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Upper Carboniferous Fusulinids from Mt. Maruyama, Mine City, Yamaguchi Prefecture

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Abstract The Middle to Upper Carboniferous Akiyoshi Limestone Group is widely distributed in the Mt. Maruyama area, Mine City, Yamaguchi Prefecture.

Limestones in this area are variable in their organic compositions, such as rugose corals, ammonoids, phylloid algae, brachiopods and fusulinids.

Lithologic facies and sedimentary features indicate a paleoenvironment of the reef flat or by-pass margin between the fore reef part of the Akiyoshi organic reef complex and open sea.

Locality MA66 is abundant in fusulinid species of primitive type- "*Triticites*". Four species, including three new ones can be discriminated as follows: *Protriticites yanagidai* Y. OTA, sp. nov., *Protriticites masamichii* Y. OTA, sp. nov., *Protriticites toriyamai* Y. OTA, sp. nov., and *Protriticites* aff. *matsumotoi* (KANMERA).

Introduction

The Akiyoshi Limestone Group is composed of the Early Carboniferous to latest Middle Permian limestones with basaltic pyroclastic rocks at the basal part (e.g. OTA, 1968; YANAGIDA *et al.*, 1971). The limestone group has an extensive distribution in Mine City, and Shuho and Mito Towns in Mine-County, Yamaguchi Prefecture, Southwest Japan (Fig. 1).

The Akiyoshi Limestone Group is generally recognized as an element of the Akiyoshi terrane, characterized by a heterogeneous complex of Carboniferous and Permian rocks (e.g. SANO and KANMERA, 1988).

Since OZAWA (1923) made the geologic structure of the Akiyoshi Limestone clear, many kinds of reseachers and, geologist and paleontologist have presented many studies on the Akiyoshi Limestone Group and its surrounding non-calcareous Paleozoic formations in the Akiyoshi region (e.g. TORIYAMA, 1958).

In the Akiyoshi region, 21 fossil zones have been established as regional chronostratigraphic units, mainly based on diagnostic fusulinid species (OTA,1977).

At present, the refinement of the Carboniferous and Permian chronostratigraphic units in the Akiyoshi region requires not only the detailed geologic mapping by the tracing of useful fossils, but also considerable paleoecological and paleoenvironmental investigations. This includes analyses of mode of fossil occurrences and fusulinid

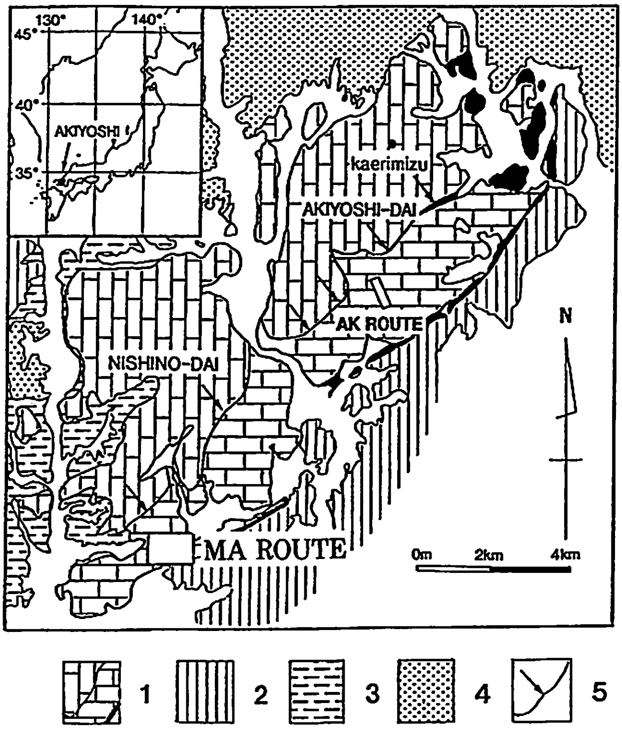

Fig. 1. Simplified geologic map of the Akiyoshi area, showing location of the study area, MA Route. 1. Akiyoshi Limestone Group. 2. Beppu Group and Ota Group. 3. Tsunemori Group. 4. Cretaceous sedimentary and igneous rocks. 5. major thrust fault.

assemblages, based on the consideration of the Akiyoshi Limestone Group as an organic reef complex (OTA, 1968; SUGIYAMA and NAGAI, 1990; OTA and OTA, 1993).

Consequently, the study of fusulinid assemblages provides us with many important facts concerned in the phylogenetic relationship of them.

This paper presents some important results of the field work carried out at the Mt. Maruyama area in Isa Quarry.

Geological Setting

Mt. Maruyama in the Isa Quarry is located in the southwestern part of the Akiyoshi limestone plateau, and widely underlain by the normal sequence of the Akiyoshi Limestone Group (Fig. 1).

The investigated area, the northeastern part of Isa Quarry, forms a small mound of limestone.

The Akiyoshi Limestone Group in this area is distributed in a homoclinal

structure with a general strike of northeastern trend and northward dip. According to KYUMA and NISHIDA (1987), the following fossil zones have been discriminated in ascending order: *Profusulinella beppensis* zone, *Fusulinella simplicata* subzone, and *Fusulinella biconica* subzone (Fig. 2).

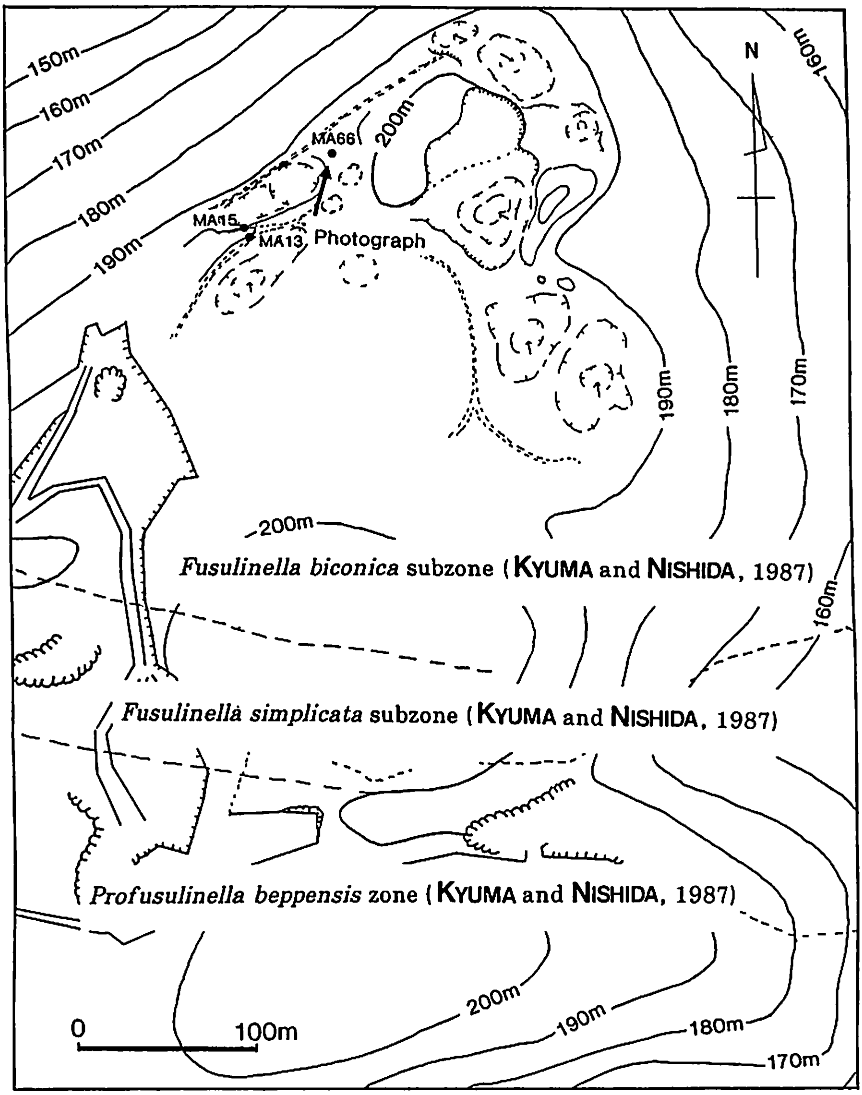

Fig. 2. Map showing the distribution of fusulinid zones in Mt. Maruyama, and locality of MA66.

Methods of this survey

The investigation area is located on the eastern slope of Mt. Maruyama and included in a huge limestone quarry with about 200 meters at the highest elevation.

The author made a measuring route to clarify the localities of collected materials, and named it as the MA Route after Mt. Maruyama (Fig. 3). The route was selected for crossing the general strike of the E-W trend at right angles and examined for the detail of the transitional changes of fusulinid assemblages along the route.

The author especially examined materials from Loc. MA66, where the abundant fusulinids have been confirmed.

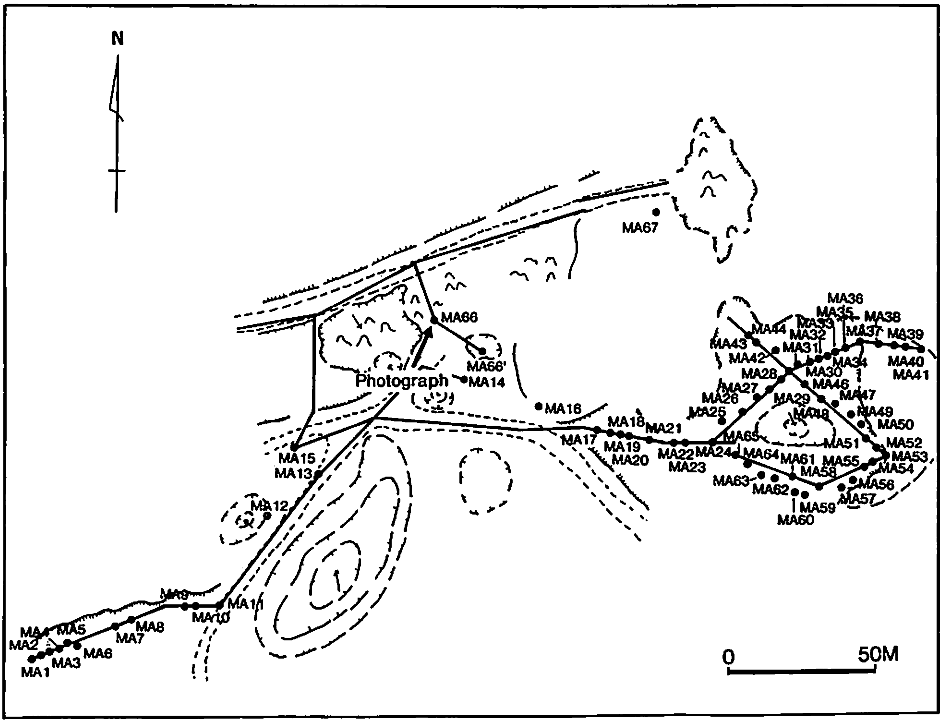

Fig. 3. Map showing the study area and measured route (MA Route).

Lithofacies

The investigation area is represented by limestones ranging from the Middle to Upper Carboniferous.

OTA (1968) regarded the limestones in this area as the true reef facies deposits characterized by stromatolites and chaetetids. Furthermore, KYUMA and NISHIDA

(1987) confirmed the biomicrite to biomicrudite, bryozoa-crinoid biosparite, and shell-crinoid biosparrudite in this area and described some well-preserved goniatites.

Limestones in the Mt. Maruyama area are considered to have been formed in a reef core environment in the Akiyoshi organic reef complex.

The author obtained the fossiliferous rock samples from the preceding Loc. MA66, where the abundant fusulinids occur. Thin sections and the polished block samples of the limestones were made for examining fusulinids and sedimentary facies (Plate 3, Fig. 7).

In addition, the author divided Block sample A into four parts, A-1, A-2, A-3 and A-4, and Block sample B into three, B-1, B-2 and the other to examine the serial polished sections (Figs. 4–6).

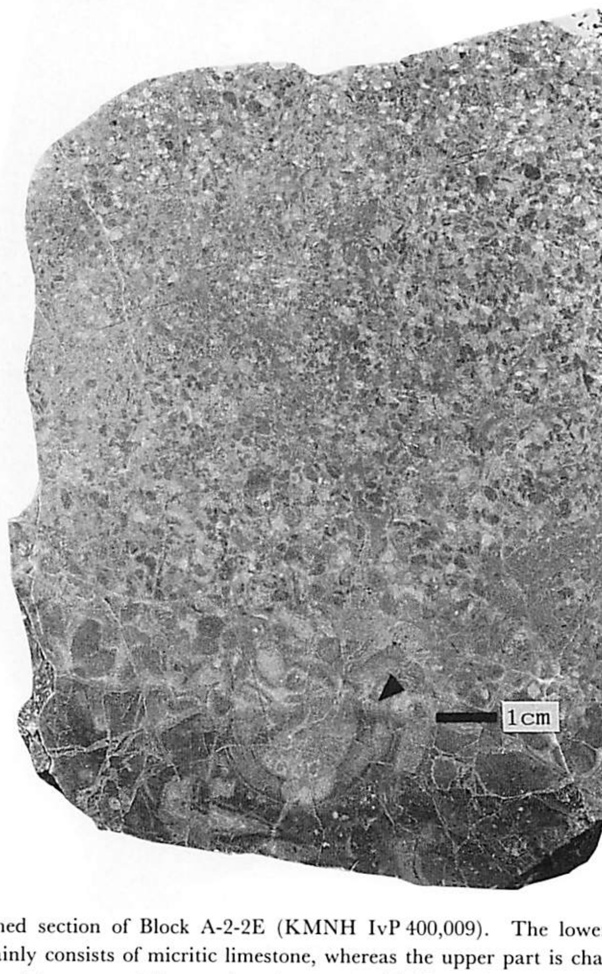

Fig. 4. Polished section of Block A-2-2E (KMNH IvP 400,009). The lower part of the figure mainly consists of micritic limestone, whereas the upper part is characterized by limestone with sparry calcite matrix. An ammonoid (shown by an arrow) is truncated, and the time gap is recognizable in the sediments.

The Block sample A is characterized by the abundance in fusulinids, while Block sample B represents a part of the boundary between micritic limestone, containing macro-fossils or coarse grains and fusulinid limestone.

On examination of Block Samples from Loc. MA66

(Polished section of Block A-2-2E) (Fig. 4)

The polished section of Block A-2-2E well indicates that the limestone from Loc.

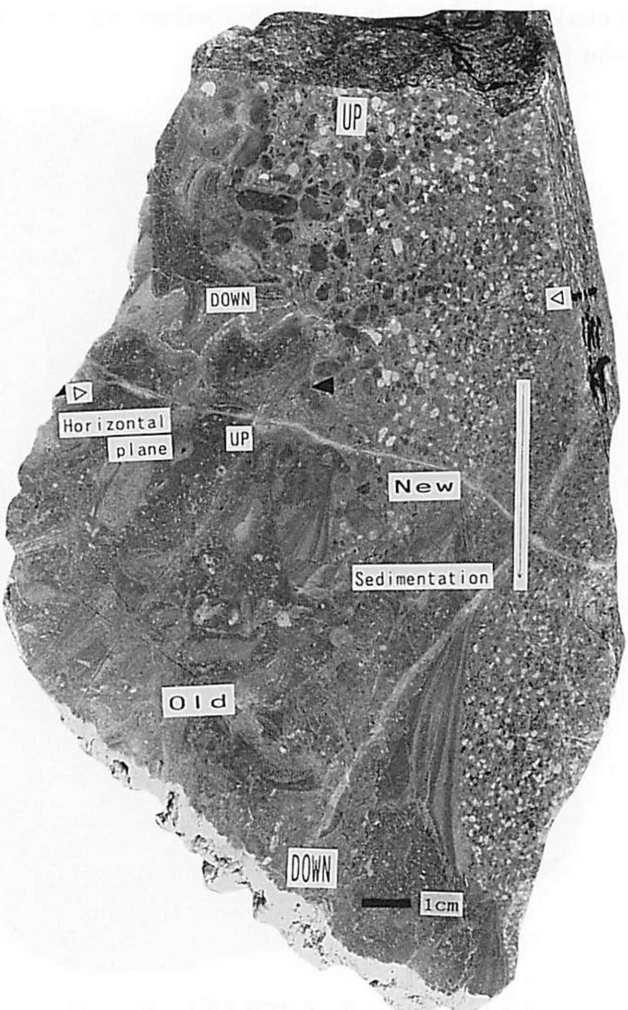

Fig. 5. Polished section of Block B-1-1 (KMNH IvP 400,010). Limestone is mainly composed of two parts, micritic part with a section of shell and grain supported part with normal grading. A geopetal fabric is observed in the cross section of a shell fragment.

MA66 generally has the matrix of sparry calcite, and occasionally the matrix changes into micritic in texture.

The lower part of the section is blackish, whereas the upper part is whitish in color. The boundary between these parts of different colors is fairly distinct but irregular.

The lower part mainly consists of micritic limestone. The upper part shows the grain-supported fabrics. The matrix of the upper part limestone is characterized by sparry calcite cements and particles from about 3 to 0.5 mm, grading finer upwards.

A fragment of ammonoid below the boundary is truncated, and a discontinuous structure during the deposition is recognizable. This evidence indicates an interruption of sedimentation, and the time gap is well marked on the Block A-2-2E.

(Polished section of Block B-1-1) (Fig. 5)

The limestone in the top of the polished section of Block B-1-1 is characterized by sparry calcite cements in its matrix. The particles with normal grading (coarse grains at the bottom= at the top in Fig. 5, and fine grains at the top=at the bottom in the same figure) mainly consist of bioclasts with range from 0.5 to 1.0 mm in size. According to the classification of DUNHAM (1962) and EMBRY and KLOVAN (1972), the limestone shown in the upper half of the figure is grain-supported limestone, i.e., grainstone. The grainstone yields abundantly well-preserved fusulinids. The lower half of the figure shows the micritic limestones with a cross-section of shell fragments. In addition, geopetal fabrics in the cross-section of shell fragments appear at the center of the figure. The fabric was caused diagenetically or by something else. From this fabric, the sediments at the upper of the figure are younger than those at the lower.

Examining the polished section of Block B-1-1 by microscope, the following depositional history of sediments is reconstructed. At first, blackish micritic sediments including the macro-fossils have been deposited and formed a ground. Then the newly transported particles were accumulated on the ground surface with the depositional gradation by grain size.

The Block B-1-1 can be interpreted as it is showing the inverted structure. To the contrary of above evidence, the geology of the Mt. Maruyama area well represents the normal succession, ranging from the Middle to Upper Carboniferous based on fusulinids and other fossils (e.g. OTA, 1977; KYUMA and NISHIDA, 1987).

Consequently, there is a possibility that the block is a collapsed breccia or debris of a reef-builder. However, the genesis is left unsolved.

(Polished section of Block B-2-1) (Fig. 6)

This figure shows a completely inverted position both longitudinally and laterally to the preceding Figure 5.

The right half of the Figure 6 shows the micritic limestone with macro-fossils and

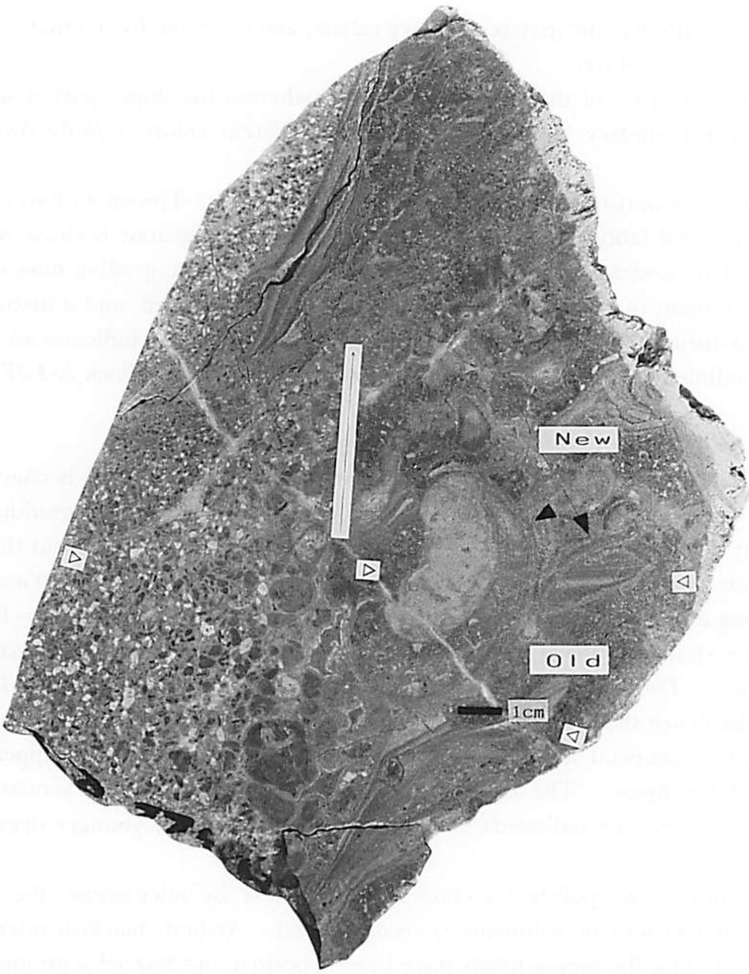

Fig. 6. Polished section of Block B-2-1 (KMNH IvP 400,011). The figure shows in inverted position to the preceding figure. Right side of the figure shows the southern direction. Oblique sections of ammonoids and mollusks are observed in micritic limestone, and the geopetal fabrics are confirmed. Judging from the top and bottom structure and the grading sediments, it is inferred that the sediments in the top of the figure are the younger ones.

Pycnoporidium sp., regarded as a group of green algae.

The oblique sections of ammonoids and mollusks with the geopetal fabrics are observed in micritic limestone. Judging from the fabrics, it is inferred that the sediments in the top of the figure are the younger ones.

Laminations with very fine grading are observed in the uppermost part of the block section.

The sediment of the left part of the figure is rich in fusulinids, and lies upon eroded ground. The discontinuity between the eroded ground and fusulinid limestone with sparry calcite matrix does not suggest that the eroded surface was partly exposed in the air. This depositional break in sedimentation is considered to be omission surface that is generally called hardground.

Consequently, the micritic limestone might have been formed on a seamount.

Based on the specific constituents of fusulinids and the field observation, the sedimentary environment of this area, at least, at Loc. MA66, is referable to a part of the reef flat or by-pass margin between fore reef and open sea.

As I noticed in the preceding chapter, the limestone exposure at Loc. MA66 is characterized by the inverted structure, and this situation is against for the general succession of limestones in this area. Therefore the more detailed investigations are required on the MA66 limestone whether it is an allochthonous block or not.

Fusulinids

Limestone with the upwards grading particles and whitish sparry calcite matrix contains the abundant and well-preserved fusulinids.

Thin section studies indicate that the fusulinids from MA66 are classified as the primitive type of "*Triticites*", i.e., *Protriticites*. Morphologically the fusulinids are divided into four species as follows: *Protriticites yanagidai* Y. OTA, sp. nov., *Protriticites masamichii* Y. OTA, sp. nov., *Protriticites toriyamai* Y. OTA, sp. nov. and *Protriticites* aff. *matsumotoi* (KANMERA).

The above four species of *Protriticites* are characterized by their small sizes compared with the known species of *Protriticites*.

Genus *Protriticites*

Historical review

Genus *Protriticites* is one of the most diagnostic genera for the Tethys regions (Ross, 1967; Ross and Ross, 1985).

The genus *Protriticites* was established by PUTRYA (1948) with *Protriticites globulus* PUTRYA, 1948 (by original designation) as the type-species.

A great deal of taxonomic and biostratigraphic work has been done and many species have been described under the genus *Protriticites* (e.g. ROZOVSKAYA, 1950; VOLOZHANINA, 1962; ISHIZAKI, 1963; NIKITINA, 1969; IGO, 1972; SHENG and SUN, 1975; ZHOU *et al.*, 1987; UENO, 1991).

However, the genus *Protriticites* has been treated so differently among the above authors that its generic definition is still ambiguous.

The validity of the genus *Protriticites*, and the affinity between other genera were discussed by many workers (RAUSER and FURSENKO, 1959; WILD, 1984; Ross and

ROSS, 1987; SHENG *et al.*, 1988; LOEBLICH and TAPPAN, 1988; GINKEL and VILLA, 1991).

These problems have been caused by the "perforated wall" or "*Protriticites*-type wall" recognizable in *Protriticites globulus* PUTRYA, 1948.

DAVYDOV (1990) proposed the phylogenetic line of *Protriticites-Montiparus-Rauserites*, and also pointed out that *Montiparus* was characterized by having the inner tectorium only in the inner volutions. According to him, the genus *Montiparus* has perforated walls not in the inner volutions, but only in the outer volutions. The

Table 1. Provisional list of species of the genus *Protriticites*

Protriticites PUTRYA, 1948
Type-species: *Protriticites globulus* PUTRYA, 1948
P. pseudomontiparus PUTRYA, 1948
P. ovatus PUTRYA, 1948
P. lutugini KIREEVA, 1949
P. nitikovkensis KIREEVA, 1949
P. pseudomontiparus procerus KIREEVA, 1949
P. lamellosus KIREEVA, 1950
P. manukalovae KIREEVA, 1950
P. parvus KIREEVA, 1950
P. plicatus KIREEVA, 1950
P. plicatus bellus KIREEVA, 1950
P. umbonoreticulatus KIREEVA, 1950
P. subschwagerinoides ROZOVSKAYA, 1950
P. pseudoumbonoplicatus CHERNOVA, 1954
P. niumaolingensis SHENG, 1958
P. rarus SHENG, 1958
P. aquilus VOLOZHANINA, 1962
P. formosus VOLOZHANINA, 1962
P. sphaericus VOLOZHANINA, 1962
P. nakahatensis ISHIZAKI, 1963
P. lamellosus diminutus NIKITINA, 1969
P. prolongus NIKITINA, 1969
P. tethydis IGO, 1972
P. fusulinelloides SHENG & SUN, 1975
P. regularis LIN, 1977
P. hunanesis LIN, 1977
P. daxinensis LIN, 1977
P. obsoletus cylindica DA, 1983
P. confectus CHEN & WANG, 1983
P. praemontiparus ZHOU, SHENG & WANG, 1987
P. minor ZHOU, SHENG & WANG, 1987
P. robustus UENO, 1991

genus *Protriticites* is considered to be distinguished from *Fusulinella* by the presence of a stable trilaminar wall without a diaphanotheca in the last volution, and from *Montiparus* by the existence of a distinct trilaminar keriothecal wall in the outer volutions.

A provisional list of species that were described under the genus *Protriticites* is shown in Table 1.

Systematic Paleontology

Order Foraminiferida Eichwald, 1830
Suborder Fusulinina Wedekind, 1937
Superfamily Fusulinacea von Moeller, 1878
Family Fusulinidae von Moeller, 1878
Subfamily Fusulinellinae Staff and Wedekind, 1910
Genus *Protriticites* Putrya, 1948

Protriticites Putrya, 1948

Type-species: *Protriticites globulus* Putrya, 1948; Trudy L'vovskogo Geologicheskogo Obshchestva pri Gosudarstvennom Universitete im. Ivana Franko, Ser. Paleontol. 1, p. 89–92, table 1, figures 1–4, by original designation.

Generic diagnosis: The genus *Protriticites* Putrya has a fusiform to ellipsoidal shell with a straight axis of coiling. The shell is medium in size with bluntly rounded poles. Proloculus is minute. Inner volutions are tightly coiled and the succeeding volutions expand rather rapidly. Spirotheca is moderately thick, but variable in thickness. Inner spirotheca is composed of a tectum, a diaphanotheca and two tectoria, but outer spirotheca has numerous alveoli. Septa are slightly fluted in the axial region. Chomata are massive and well developed.

Remarks: The definition of the genus *Protriticites* is slightly different by each author and consequently some serious confusion has been caused.

The generic characteristics of *Protriticites* were defined by Putrya (1948) based on *Protriticites globulus* Putrya, 1948, the type species of this genus. The problem concerning the determination of *Protriticites* is mainly caused by the "*Protriticites*-type wall" in outer volutions of the shell.

Protriticites globulus is characterized by having an inflated fusiform with slightly concave lateral slopes and rather sharply pointed poles. The shell rapidly becomes narrower toward the polar area. Mature shell attains five to seven volutions, sometimes seven and a half volutions. The first volution is almost spherical in shape. The axis of coiling becomes gradually extended in the following three or four volutions, but extends more rapidly in outer ones. Spirotheca is characterized by

perforations like alveoli structure in outer volutions. The thickness of the spirotheca gradually increases from the inner volutions to the outer ones. Septa are weakly fluted in the central portion, but moderately fluted in the polar regions. Chomata are well developed throughout the shell. Inner chomata are broad and massive, and the outer ones are subquadrangluar and narrower in shape.

The genus *Protriticites* is considered as an intermediate form between schwagerinids and fusulinellids.

Protriticites yanagidai Y. OTA, sp. nov.

Pl. 1, figs. 1–7

Etymology: This specific name is dedicated to Professor Juichi YANAGIDA of Kyushu University. He supervised me in the study of fusulinid paleontology of the Akiyoshi Limestone Group and gave me important suggestions on this study.

Material:
Holotype:—Axial section: MA66(1a), KMNH IvP 400,001; Figure 1 of Plate 1.
Paratypes:—Axial sections: MA66(1b), MMHF100051; MA66(1d)-1, MMHF 100052; MA66(1e), MMHF100053; MA66(1f), MMHF100054; MA66(1g)-2, MMHF100055; MA66-1(I)-2, MMHF100056; MA66(3b)-2, MMHF100057 and MA66(3-2s2), MMHF100058 from Locality MA66. Sagittal sections: MA66(1sa), KMNH IvP 400,002 and MA66(1sb)-1, MMHF100059 from the preceding locality.

Locality: Loc. MA66 is located at Mt. Maruyama in the Isa Quarry, southwestern part of the Akiyoshi limestone plateau.

Description: The shell is small for the genus, and fusiform to ellipsoidal in the outline with an almost straight axis of coiling, slightly and irregularly convex lateral slopes and somewhat sharply pointed poles. Mature shells attain four and a half to five volutions in most specimens, but rarely attain five and a half volutions. The axial length ranges from 1.81 to 2.70 mm and the median width is from 1.03 to 1.52 mm, giving form ratios of 1.42± to 2.24. Average form ratio of eight specimens is 1.83. The holotype with five volutions is 2.65 mm in the axial length and 1.32 mm in the median width, giving a form ratio of 2.00.

The first volution is almost spherical in shape; the following one or two volutions are ellipsoidal to short fusiform. The axis of coiling extends slowly in the following two volutions, but more rapidly elongates in the last one or two volutions.

Averages of the ratios of the half length to the radius vector of the first to fifth volution of eight specimens are 1.14, 1.69, 2.12, 2.13 and 1.87±, respectively.

The proloculus is small and spherical, with an outside diameter of 0.02 to 0.12 mm, averaging 0.07 mm for seven specimens. The shell is tightly coiled in the first

two volutions, but expands rather rapidly in the outer ones.

Average radius vectors of the first to fifth volution for eight specimens are 0.08, 0.13, 0.21, 0.36, and 0.61+, respectively.

The chambers of the coiled part are much shorter in the direction of coiling than their width measured parallel to the axis of coiling. The chambers are widest in the center of the shell and are reduced to about zero width at the poles. The chambers increase in height gradually in the inner volutions, but in the outer ones, they increase rapidly.

The spirotheca is moderately and relatively thick to its size. The spirotheca in the inner volutions consists of four layers; a tectum, a diaphanotheca, thin upper and lower tectoria. The diaphanotheca, however, is variable in thickness, and usually very thin and indistinct. The spirotheca of outer one or two volutions is composed of a tectum, thick underlying layer with fine alveolar porosity, and a very thin outer tectorium. Averages of the thickness in the first to fifth volution for eight specimens are 0.013, 0.021, 0.029, 0.041, and 0.061, respectively. The wall of proloculus is very thin and consists of a single homogeneous layer. The thickness of the wall averages 0.013 mm in seven specimens.

The septa are relatively thick and composed of tectum and pycnotheca in the posterior side. They are almost straight in the central portion of shell, and weakly fluted in the polar regions. Average septal counts of the first to fifth volution are 8, 12, 16, 21 and 14+, respectively.

The chomata are well developed through the shell-growth, and the massive ones are asymmetrical and prominent like *Fusulinella* Moeller, 1877. The tunnel sides of the chomata are very steep, almost perpendicular, but the poleward slopes are commonly very gentle, and extend into the polar regions.

The tunnel is narrow in the inner one or two volutions, and becomes wide in the

Table 2. Measurements (in mm) of *Protriticites yanagidai* sp. nov.

	L.	W.	R.	Prol. D.	Prol. wall
MA66(1a)	2.65	1.32	2.00	0.05	0.014
MA66(1b)	2.45+	1.42+	1.72±	0.12	0.012
MA66(1d)-1	1.81+	1.27+	1.42±	0.12	0.012
MA66(1e)	2.70	1.52	1.77	0.05	0.017
MA66(1f)	2.30	1.03	2.24	0.05	0.014
MA66(1g)-2	2.11	1.03	2.05	?	?
MA66(3b)-2	1.96+	1.18+	1.67±	0.02	0.010
MA66(3-2s2)	2.21+	1.23+	1.80±	0.05	0.010
MAX.	2.70	1.52	2.24	0.12	0.017
MIN.	1.81+	1.03	1.42±	0.02	0.010
AVER.	2.27+	1.25+	1.83±	0.07	0.013

Radius vector						
volution	1	2	3	4	5	6
MA66(1a)	0.10	0.14	0.24	0.41	0.67	
MA66(1b)	0.10	0.14	0.22	0.38	0.67	
MA66(1d)-1	0.10	0.19	0.29	0.43	0.72	
MA66(1e)	0.07	0.12	0.19	0.34	0.55	0.79+
MA66(1f)	0.07	0.14	0.22	0.43	0.58+	
MA66(1g)-2	0.05	0.12	0.19	0.31	0.53	
MA66(3b)-2	0.07	0.12	0.19	0.36	0.62+	
MA66(3-2s2)	0.05	0.07	0.14	0.24	0.50	0.55+
MAX.	0.07	0.19	0.29	0.43	0.72	0.79+
MIN.	0.05	0.07	0.14	0.24	0.50	0.55+
AVER.	0.08	0.13	0.21	0.36	0.61+	0.67+

Ratio of Hl./Rv.						
volution	1	2	3	4	5	6
MA66(1a)	1.25	1.67	2.00	2.00	2.00	
MA66(1b)	1.25	2.50	2.78	2.81	1.96±	
MA66(1d)-1	1.00	1.25	1.50	1.83	1.60	
MA66(1e)	1.00	1.80	2.25	2.07	2.13	1.85±
MA66(1f)	1.33	2.00	2.44	2.22	1.88±	
MA66(1g)-2	1.50*	1.40	1.63	2.00	1.91	
MA66(3b)-2	0.75	1.60	1.88	1.67	1.54±	
MA66(3-2s2)	1.00	1.33	2.50	2.40	1.90	1.96±
MAX.	1.40	2.50	2.77	2.81	2.13	1.96±
MIN.	0.75	1.25	1.50	1.67	1.54	1.85±
AVER.	1.14	1.69	2.12	2.13	1.87±	1.91±

Thickness of spirotheca						
volution	1	2	3	4	5	6
MA66(1a)	0.014	0.034	0.034	0.053	0.048	
MA66(1b)	0.010	0.019	0.024	0.034	0.048	
MA66(1d)-1	0.019	0.036	0.036	0.043	0.048	
MA66(1e)	0.012	0.014	0.036	0.031	0.067	0.067
MA66(1f)	0.014	0.019	0.019	0.053	0.086	
MA66(1g)-2	0.014	0.019	0.029	0.048	0.067	
MA66(3b)-2	0.010	0.014	0.034	0.038	0.062	
MA66(3-2s2)	0.010	0.014	0.019	0.024	0.062	
MAX.	0.019	0.036	0.036	0.053	0.086	0.067
MIN.	0.010	0.014	0.019	0.024	0.048	0.067
AVER.	0.013	0.021	0.029	0.041	0.061	0.067

Tunnel angle						
volution	1	2	3	4	5	6
MA66(1a)	17	18	27	42		
MA66(1b)	23	25	30	36		
MA66(1d)-1	18	22	26	31?		
MA66(1e)	17	22	27	34	25?	
MA66(1f)	15	27	29	34		
MA66(1g)-2	20	24	27	29		
MA66(3b)-2	14	25	31	20?		
MA66(3-2s2)	12	24	27	39?		
MAX.	23	27	31	42	25?	
MIN.	12	18	26	20	25?	
AVER.	17	23	28	33?	25?	

Septal count						
volution	1	2	3	4	5	6
MA66(1sa)	8	12	16	20	22+	
MA66(1sb)-1	8	12	15	21	6+	
MAX.	8	12	16	21	22+	
MIN.	8	12	15	20	6+	
AVER.	8	12	16	21	14+	

outer three or four volutions. The path is almost straight. Averages of the tunnel angles of the first to fourth volution in eight specimens are 17, 23, 28, and 33 degrees, respectively.

Remarks and comparison: *Protriticites yanagidai* belongs to a rather primitive member of the genus.

Protriticites yanagidai resembles the type-species, *P. globulus* PUTRYA in general shape and internal structures. However, the latter has much larger size and number of volutions at the maturity, and more sharply pointed poles and larger tunnel than the former.

Protriticites yanagidai closely resembles *Protriticites matsumotoi* (KANMERA), that was first described by KANMERA (1955) from the Yayamadake Limestone in Kumamoto Prefecture under the name of *Triticites*. *Protriticites yanagidai* is distinguished from *P. matsumotoi* in having much smaller size and smaller number of volutions. In addition, *P. yanagidai* expands more rapidly in the outer volutions, comparing with the expansion rate of *P. matsumotoi*.

The indistinct chomata, shortly inflated fusiform and small size of *Protriticites yanagidai* suggest a close relation to *Protriticites pseudomontiparus*, reported by PUTRYA

(1948) together with *P. globulus* and *P. ovatus* from Severo-Kamenskiy and Belokalitvenskiy regions, and Donbassa, Russia. However, *P. yanagidai* can be distinguished from *P. pseudomontiparus* by its smaller size, smaller number of volutions and stronger septal fluting. *Protriticites yanagidai* differs from *P. ovatus* in having the smaller shell with more sharply pointed poles and relatively simple internal structures.

ROZOVSKAYA (1950) described two species of *Protriticites* from the Upper Carboniferous of Podmoskov'e in the paper on the development and stratigraphic significance of the genus *Triticites*. Of them, *Protriticites subschwagerinoides* resembles *P. yanagidai* in general form of shell and internal features. However, the major differences between them are that *P. subschwagerinoides* has larger and more cylindrical shell with more bluntly pointed poles at maturity. *Protriticites subschwagerinoides* is characterized by having the ontogenetic transition of spirothecal structure that is from the inner four layered spirotheca to the outer protheca through the three layered spirotheca in the middle stage of growth. However, this ontogenetic spirothecal transition is not clear in the *P. yanagidai*.

SHENG and SUN (1975) described *Protriticites fusulinelloides* as fusulinids from the Middle Carboniferous of Maque, Qinghai, central part of China. This species also resembles *P. yanagidai* in several characters. However, *P. yanagidai* can be distinguished from *P. fusulinelloides* by its smaller size and shortly inflated shell with more massive and broader chomata.

Protriticites praemontiparus and *P. minor* were described by ZHOU *et al.* (1987) from the lowest fusulinid zone, *Protriticites subschwagerinoides* in the Xiaodushan section, eastern Yunnan, South China. The two species are similar to *P. yanagidai* in general appearance. However, *P. praemontiparus* is considerably larger and has more bluntly pointed poles and more ellipsoidal form than the present species at the mature stage of growth. *Protriticites minor* has the almost same size and form as *P. yanagidai*, but differs from the latter in its shorter inflated fusiform with bluntly pointed poles.

Occurrence: The coarse grained limestone with *Protriticites yanagidai* is distributed sporadically in the reef facies limestone. The reef limestone in this area comprises many green algae, such as *Pycnoporidium* sp. and also phylloid algae. *Protriticites yanagidai* is also accompanied by the macro- and micro-fossils of other kinds in the Akiyoshi organic reef complex.

Geological age: Late Carboniferous (Kassimovian), *Protriticites matsumotoi* zone of the Akiyoshi Limestone Group.

Repository: The holotype, KMNH IvP 400,001 is preserved in Kitakyushu Museum and Institute of Natural History. Remainders of the studied materials will be divisibly kept in the Kitakyushu Museum and Institute of Natural History and Mine City Museum.

Protriticites masamichii Y. OTA, sp. nov.

Pl. 2, figs. 1–7

Etymology: The specific name is dedicated to Dr. Masamichi OTA, Director of the Kitakyushu Museum and Institute of Natural History, who has greatly contributed to the geology and paleontology of the Akiyoshi Limestone Group, and first introduced an idea of Akiyoshi organic reef complex for the Akiyoshi Limestone Group.

Material:
Holotype:—Axial section: MA66(2a-1), KMNH IvP 400,003; Figure 2 of Plate 2.
Paratypes:—Axial sections: MA66(2b), MMHF100060; MA66(2c-2), MMHF 100061; MA66(2d), MMHF100062; MA66(2e-1, 2e-2), MMHF100063; MA66(2f), MMHF100064; MA66(2g), MMHF100065; MA66(2h), MMHF100066; MA66(2i), MMHF100067; MA66(2j), MMHF100068; MA66(2k), MMHF100069 and MA66(2l), MMHF100070, respectively from Loc. MA66. Sagittal section: MA66(2s), KMNH IvP 400,004 from Loc. MA66.

Locality: Locality MA66, at Mt. Maruyama in the Isa Quarry, Mine City, Yamaguchi Prefecture.

Description: The shell is small and moderately inflated oval to subspherical, and it has an almost straight axis of coiling, convex lateral slopes and bluntly pointed poles. Mature specimens show 2.01+ to 2.60+mm in length, and 1.27 to 1.57 mm in width, and form ratios of 1.40 to 1.89±, respectively at a growth stage from four and a half to five and a half volutions. Average form ratio of 13 specimens is 1.61±.

The five volutions of the holotype show 2.45 mm in axial length and 1.57 mm in median width with a form ratio of 1.56.

The proloculus is small to medium, 0.01 to 0.10 mm in outside diameter. The first to third volutions have massive chomata like *Fusulinella* and are tightly coiled with subglobose form. Succeeding volutions expand rapidly, increasing in height and length, and the shell becomes oval to subspherical with perched and subquadrate chomata at a growth stage of the fifth or fifth and a half volution.

Averages of the ratios of the half length to the radius vector of the first to fifth volution of 13 specimens are 1.37, 1.48, 1.76, 1.78, and 1.62±, respectively.

The spirotheca of the inner volutions is composed of a tectum, a very thin and indistinct diaphanotheca and thin upper and lower tectoria. The outer spirotheca consists of three layers; a tectum, a more prominent and perforated lower tectorium, and, a thin and inconstant upper tectorium. The average thicknesses of the spirotheca in the first to fifth volution of 13 specimens are 0.014, 0.021, 0.037, 0.057 and 0.066, respectively.

The septa are almost straight in the central portion of the shell, but moderately

fluted in the axial region and more fluted toward the poles. The septal counts of the first to fifth volution are 9, 11, 14, 18 and 20, respectively.

The chomata are well developed in all volutions. The tunnel sides of chomata

Table 3. Measurements (in mm) of *Protriticites masamichii* sp. nov.

	L.	W.	R.	Prol. D.	Prol. wall
MA66(2a-1)	2.45	1.57	1.56	0.07	0.010
MA66(2b)	2.35+	1.47+	1.60±	0.05	0.014
MA66(2c-2)	2.55+	1.52+	1.68±	0.05	0.014
MA66(2d)	2.30	1.37	1.68	0.01	0.014
MA66(2e-1)	2.60+	1.37+	1.89±	0.07	0.014
MA66(2e-2)	2.30+	1.42+	1.62±	0.05	0.010
MA66(2f)	2.06	1.47	1.40	0.05	0.010
MA66(2g)	2.21	1.27	1.73	0.02	0.005
MA66(2h)	2.11	1.27	1.65	0.05	0.019
MA66(2i)	2.11+	1.32+	1.59±	0.04	0.005
MA66(2j)	2.06	1.42	1.45	0.05	0.007
MA66(2k)	2.35	1.47	1.60	0.10	0.014
MA66(2l)	2.01+	1.32+	1.52±	0.05	0.005
MAX.	2.60+	1.57	1.89±	0.10	0.014
MIN.	2.01+	1.27	1.40	0.01	0.005
AVER.	2.27+	1.41+	1.61±	0.05	0.010

Radius vector						
volution	1	2	3	4	5	6
MA66(2a-1)	0.07	0.12	0.19	0.36	0.67	
MA66(2b)	0.05	0.10	0.19	0.34	0.62	0.84+
MA66(2c-2)	0.05	0.12	0.24	0.41	0.67	0.82+
MA66(2d)	0.07	0.17	0.29	0.48	0.77	
MA66(2e-1)	0.12	0.19	0.34	0.60	0.70+	
MA66(2e-2)	0.05	0.12	0.24	0.41	0.67	0.72+
MA66(2f)	0.07	0.14	0.24	0.48	0.55	
MA66(2g)	0.07	0.14	0.24	0.34	0.67	
MA66(2h)	0.07	0.10	0.19	0.36	0.65	
MA66(2i)	0.05	0.12	0.19	0.31	0.53	0.67+
MA66(2j)	0.07	0.14	0.24	0.43	0.67	
MA66(2k)	0.10	0.19	0.31	0.48	0.74	
MA66(2l)	0.05	0.07	0.17	0.26	0.43	0.70+
MAX.	0.12	0.19	0.34	0.48	0.77+	0.84+
MIN.	0.05	0.07	0.17	0.26	0.43	0.67+
AVER.	0.07	0.13	0.24	0.41	0.64	0.75+

Ratio of Hl./Rv.						
volution	1	2	3	4	5	6
MA66(2a-1)	1.00	1.20	2.13	2.47	1.79	
MA66(2b)	2.00	2.00	2.13	2.00	1.73	1.46±
MA66(2c-2)	2.00	1.60	1.60	1.65	1.50	1.79±
MA66(2d)	1.67	1.71	1.83	2.00	1.34	
MA66(2e-1)	1.20	2.00	2.07	1.52	1.90±	
MA66(2e-2)	1.00	1.40	1.50	1.35	1.25	1.50±
MA66(2f)	1.33	1.67	2.00	1.60	2.22	
MA66(2g)	1.67	1.33	1.50	2.00	1.61	
MA66(2h)	1.00	1.25	1.50	1.67	1.67	
MA66(2i)	1.00	1.40	1.50	1.54	1.36	1.43±
MA66(2j)	1.67	1.67	2.00	1.72	1.50	
MA66(2k)	1.50	1.25	1.69	1.75	1.55	
MA66(2l)	0.75	0.75	1.43	1.82	1.67	1.48±
MAX.	2.00	2.00	2.13	2.47	2.22	1.79±
MIN.	0.75	0.75	1.43	1.35	1.25	1.43±
AVER.	1.37	1.48	1.76	1.78	1.62±	1.53±

Thickness of spirotheca						
volution	1	2	3	4	5	6
MA66(2a-1)	0.014	0.014	0.024	0.072	0.062	
MA66(2b)	0.014	0.019	0.053	0.062	0.086	0.067
MA66(2c-2)	0.014	0.024	0.034	0.062	0.086	0.077
MA66(2d)	0.024	0.014	0.058	0.043	0.067	
MA66(2e-1)	0.014	0.029	0.043	0.067	0.072	
MA66(2e-2)	0.010	0.014	0.019	0.029	0.034	0.034
MA66(2f)	0.014	0.024	0.038	0.086	0.086	
MA66(2g)	0.010	0.024	0.043	0.062	0.120	
MA66(2h)	0.010	0.014	0.024	0.062	0.048	
MA66(2i)	0.014	0.024	0.029	0.043	0.062	0.062
MA66(2j)	0.014	0.019	0.038	0.058	0.029	
MA66(2k)	0.014	0.029	0.038	0.062	0.053	
MA66(2l)	0.014	0.019	0.038	0.024	0.053	0.072
MAX.	0.024	0.029	0.058	0.086	0.120	0.077
MIN.	0.010	0.014	0.019	0.024	0.029	0.034
AVER.	0.014	0.021	0.037	0.057	0.066	0.062

Tunnel angle						
volution	1	2	3	4	5	6
MA66(2a-1)	16	23	28	33		
MA66(2b)	11	20	29	29		
MA66(2c-2)	12	21	24	30	34	
MA66(2d)	22	23	32	43		
MA66(2e-1)	13	19	30	34		
MA66(2e-2)	12	20	28	37		
MA66(2f)	11	23	28	31		
MA66(2g)	6	15	24	36		
MA66(2h)	12	17	28	35		
MA66(2i)	15	15	19	30	30	
MA66(2j)	9	17	20	24		
MA66(2k)	11	22	26	28		
MA66(2l)	10	22	34	35	38	
MAX.	22	23	34	43	38	
MIN.	6	15	19	24	30	
AVER.	12	20	27	33	34	

Septal count						
volution	1	2	3	4	5	6
MA66(2s)	9	11	14	18	20	6+

are very steep, almost perpendicular in the inner volutions, and occasionally overhanging in the outer volutions. The poleward slopes, on the other hand, in the inner volutions are very gentle and extend into the polar regions, but the outer ones are moderately steep. The tunnel is a third to almost a half as high as the chamber. Averages of the tunnel angles of the first to fifth volution of 13 specimens are 12, 20, 27, 33, and 34* (*three specimens), respectively.

Remarks and comparison: *Protriticites masamichii* also resembles the type species of the genus, *P. globulus* PUTRYA, 1948, in general shape and internal structures. However, *P. masamichii* is distinguished from *P. globulus* and most of other species under this genus by its very small and inflated, oval to subspherical with the heavy chomata.

Protriticites yanagidai resembles the present species in its small size and massive chomata. These two species are undoubtedly very closely related to each other. However, the former is distinguished from the latter by its fusiform to ellipsoidal outline of the shell, and by its somewhat sharply pointed poles.

Protriticites masamichii is distinguished from *P. matsumotoi* (KANMERA) by its much smaller and more inflated shell than the latter.

Protriticites masamichii resembles the preceding *P. pseudomontiparus* and *P. ovatus* in several respects. However, *P. pseudomontiparus* is generally larger and more highly fusiform in shape than *P. masamichii*. *Protriticites ovatus* is distinct from *P. masamichii* by its larger shell with more sharply pointed poles and in having highly fluted septa.

Protriticites subschwagerinoides ROZOVSKAYA, 1950, from the Upper Carboniferous of Podmoskov'e, Russia is also similar to *P. masamichii* in having shortly inflated shell. However, *P. masamichii* differs from *P. subschwagerinoides* in its smaller and weaker fusiform shell with less sharply pointed poles and lager number of volutions.

Protriticites sphaericus VOLOZHANINA, 1962, from the Upper Carboniferous of Timano-Pechorskoi, north of Russia, resembles *P. masamichii* in the outline of shell. However, the former species is easily distinguished from the latter by its relatively larger size and larger number of volutions.

Protriticites fusulinelloides SHENG and SUN, 1975, from the Middle Carboniferous of Qinghai, central part of China is similar to *P. masamichii* in general shape of shell. It differs, however, from the latter in having more elongated fusiform and much larger shell.

Protriticites praemontiparus ZHOU, SHENG and WANG, 1987, from Xiaodushan, South China, resembles *P. masamichii* in having fusiform shell and indistinct diaphanotheca. However, *P. praemontiparus* has a more ellipsoidal outline and relatively less massive chomata than the latter. *Protriticites minor* ZHOU, SHENG and WANG, 1987, from the preceding area also closely resembles *P. masamichii* in general shape and size. The major differences between them are that the latter species has a smaller proloculus and more distinct chomata than the former. In regard to spirothecal structure, *P. minor* has two outer volutions with very fine, distinct alveolar structure. On the other hand, *P. masamichii* has the spirothecal structure composed of very fine and distinct alveoli in outer volutions. The close similarity of the characters between them suggests that *P. masamichii* has a close relationship to *P. minor*.

Occurrence: *Protriticites masamichii* abundantly occurs at Loc. MA 66, Mt. Maruyama. It is closely associated with *Protriticites yanagidai* in this area.

Geological age: Late Carboniferous (Kassimovian), *Protriticites matsumotoi* zone of the Akiyoshi Limestone Group.

Repository: The holotype, KMNH IvP 400,003 is preserved in Kitakyushu Museum and Institute of Natural History. Remainders of the studied materials will be divisibly kept in the Kitakyushu Museum and Institute of Natural History and Mine City Museum.

Protriticites toriyamai Y. OTA, sp. nov.

Pl. 3, figs. 1–4

Etymology: The specific name is dedicated to late Dr. Ryuzo TORIYAMA, Emeritus Professor of Kyushu University, and the former Director of the Kitakyushu Museum and Institute of Natural History, who greatly contributed to the knowledge of the geology and the paleontology of the Akiyoshi Limestone Group.

Material:
Holotype:—Axial section: MA66(3a), KMNH IvP 400,005; Figure 3 of Plate 3.
Paratypes:—Axial sections: MA66(1g)-1, MMHF100055; MA66(II), MMHF 100071; MA66(3b)-1, MMHF100072 and MA66(3c)-2, KMNH IvP 400,006 from Loc. MA66. Sagittal sections: MA66(3-1s), KMNH IvP 400,007; MA66(3-2s1), MMHF100058 and MA66(3-3s1, 3-3s2), MMHF100073 from Loc. MA66.

Locality: Loc. MA66, at Mt. Maruyama in the Isa Quarry, Mine City, Yamaguchi Prefecture.

Description: The shell is very small and shortly fusiform with bluntly pointed poles. The axis of coiling is constant and the lateral slopes are convex. Mature shells are composed of four and a half or five volutions at most. The axial length is 1.47+ to 1.76+mm and the median width is 0.88+ to 1.08+mm, giving a form ratio of 1.59 to 1.75+. Average form ratio of five specimens is 1.67±.

The first volution is almost spherical in shape. The following one or two volutions are shortly fusiform with more or less bluntly pointed poles. The outer volutions are relatively less elongate fusiform and have very slightly extended poles. Averages of the ratios of the half length to the radius vector of the first to fifth volution for five specimens are 1.28, 1.59, 1.77, 1.62 and 1.70±, respectively. The fourth and a half volution of the holotype shows 1.72+mm in the axial length and 0.98+mm in the median width, giving a form ratio of 1.75±.

The proloculus is spherical and relatively medium to small for the size of shell. Its outside diameter measures 0.05 to 0.01 mm, averaging 0.07 mm for five specimens. The shell expands slowly in the inner volutions, but rather rapidly expands in the following volutions toward maturity, and gradually becomes shortly fusiform. The averages of the radius vectors of the first to fifth volution of five specimens are 0.07, 0.13, 0.23, 0.41 and 0.52+ mm, respectively.

The spirotheca in the inner volutions is composed of a tectum, a very thin and indistinct diaphanotheca, and thin upper and lower tectoria. Outer one or two volutions consist of three layers, a tectum, a more prominent and perforated lower tectorium, and a thin and inconstant upper tectorium. The proloculus wall seemingly consists of a single, homogeneous dense layer, measuring 0.005 to 0.014

mm and averaging about 0.010 mm for five specimens. Average thicknesses of the spirotheca of the first to fifth volution for five specimens are 0.012, 0.015, 0.037, 0.057 and 0.064 mm, respectively.

The septa are moderately fluted in the axial region, and become more fluted toward the poles. Average septal counts of the first to fourth and a half volution for four specimens are 8, 12, 13, 15 and 15+, respectively. The chomata are asymmet-

Table 4. Measurements (in mm) of *Protriticites toriyamai* sp. nov.

	L.	W.	R.	Prol. D.	Prol. wall
MA66(3a)	1.72+	0.98+	1.75±	0.05	0.010
MA66(3b)-1	1.47+	0.88+	1.67±	0.10	0.014
MA66(3c)-2	1.72	1.08	1.59	0.05	0.005
MA66(1g)-1	1.67+	0.98+	1.70±	0.10	0.010
MA66(II)	1.76+	1.08+	1.64±	0.05	0.010
MAX.	1.76+	1.08+	1.75±	0.10	0.014
MIN.	1.47+	0.88+	1.59	0.05	0.005
AVER.	1.67+	1.00+	1.67±	0.07	0.010

Radius vector						
volution	1	2	3	4	5	6
MA66(3a)	0.07	0.12	0.22	0.41	0.53+	
MA66(3b)-1	0.05	0.10	0.17	0.31	0.43+	
MA66(3c)-2	0.05	0.12	0.17	0.31	0.50	
MA66(1g)-1	0.10	0.14	0.24	0.43	0.53	
MA66(II)	0.10	0.19	0.36	0.58	0.60+	
MAX.	0.10	0.19	0.36	0.58	0.60+	
MIN.	0.05	0.10	0.17	0.31	0.43+	
AVER.	0.07	0.13	0.23	0.41	0.52+	

Ratio of Hl./Rv.						
volution	1	2	3	4	5	6
MA66(3a)	1.00	1.60	1.67	1.59	1.73±	
MA66(3b)-1	1.00	1.00	1.29	1.38	1.66±	
MA66(3c)-2	0.66	1.20	1.57	1.77	1.90	
MA66(1g)-1	2.00	2.00	2.50	1.78	1.59±	
MA66(II)	1.75	2.13	1.80	1.58	1.60±	
MAX.	2.00	2.13	2.50	1.78	1.90	
MIN.	0.66	1.00	1.29	1.38	1.60±	
AVER.	1.28	1.59	1.77	1.62	1.70±	

Thickness of spirotheca						
volution	1	2	3	4	5	6
MA66(3a)	0.014	0.014	0.043	0.086	0.072	
MA66(3b)-1	0.005	0.010	0.029	0.038	0.053	
MA66(3c)-2	0.010	0.010	0.024	0.034	0.062	
MA66(1g)-1	0.014	0.019	0.034	0.062	0.062	
MA66(II)	0.014	0.024	0.058	0.062	0.072	
MAX.	0.014	0.024	0.058	0.086	0.072	
MIN.	0.005	0.010	0.024	0.034	0.053	
AVER.	0.012	0.015	0.037	0.057	0.064	

Tunnel angle						
volution	1	2	3	4	5	6
MA66(3a)	9?	20	31	40		
MA66(3b)-1	13	26	28	30		
MA66(3c)-2	12	25	28	33		
MA66(1g)-1	16	21	25	26		
MA66(II)	22	27	27	39		
MAX.	22	27	31	40		
MIN.	9?	20	25	26		
AVER.	14	24	28	33		

Septal count						
volution	1	2	3	4	5	6
MA66(3-1s)	9	13	14	16	16+	
MA66(3-2s1)	9	11	11	14	18+	
MA66(3-3s1)	9	14	15	14		
MA66(3-3s2)	6	11	12	14	11+	
MAX.	9	14	15	16	18+	
MIN.	6	11	11	14	11+	
AVER.	8	12	13	15	15+	

rical, massive and broad in early volution, the later ones subquadrate, relatively low and narrow. The poleward slopes of the chomata are gentle in the inner volution and become steep in the outer ones. The tunnel is narrow in the first volution, but expands in width beyond the second volution. Averages of the tunnel angles in the first to fourth volution of five specimens are 14, 24, 28 and 33 degrees, respectively.

Remarks and comparison: *Protriticites toriyamai* is characterized by the very small shell in comparison with the preceding two species, *P. yanagidai* and *P. masamichii*. *Protriti-*

cites toriyamai is not considered to represent a younger stage of *P. yanagidai* or *P. masamichii* but should be an independent species, because *P. toriyamai* usually has four or five volutions.

Protriticites toriyamai resembles *P. globulus* PUTRYA, 1948, in having inflated shell and the perforated wall in outer volutions. The former, however, differs from the latter in having the larger shell, a larger number of volutions, and more sharply pointed poles. *Protriticites pseudomontiparus* PUTRYA, 1948, and *P. ovatus* PUTRYA, 1948, also resemble *P. toriyamai* in having inflated shell and perforated wall in outer volutions. However, *P. toriyamai* is distinguishable from the former two species in having the smaller and shorter fusiform shell with less concave lateral slopes, and more bluntly pointed to rounded poles.

Protriticites toriyamai resembles *Protriticites matsumotoi* (KANMERA, 1955). However, the former can be distinguished from the latter by its smaller size, less inflated fusiform, and more rounded to bluntly pointed poles.

Protriticites nakahatensis ISHIZAKI, 1963, from the Upper Carboniferous Nakahata Formation, Gifu Prefecture and *Protriticites robustus* UENO, 1991 from the Upper Carboniferous *Protriticites* sp. zone of the Akiyoshi Limestone Group differ from *P. toriyamai* in having the larger shell.

A variation of *Protriticites tethydis* IGO, 1972, from the Upper Carboniferous of the Rat Buri Limestone, Thailand (Plate 12, figure 16) resembles *P. toriyamai* in its small and inflated fusiform shell. The holotype of *P. tethydis* (Plate 12, figure 13) can be distinguished from the latter by its larger shell and more sharply pointed poles.

Protriticites sphaericus VOLOZHANINA, 1962 from the Upper Carboniferous of Timano-Pechorskoi, north of Russia resembles *P. toriyamai* in general shape. However, the most pronounced differences are that *P. sphaericus* has the larger shell and larger number of volutions with relatively more massive chomata.

Protriticites prolongus NIKITINA, 1968, from the *Obsoletes-Protriticites* zone of the Upper Carboniferous, Primorskogo, Russia can be distinguished from *P. toriyamai* by its much larger, more highly elongated and more cylindrical shell. *Protriticites lamellosus diminutus* NIKITINA, 1968, from the *Obsoletes-Protriticites* zone of the Upper Carboniferous, Primorskogo, Russia also resembles *P. toriyamai* in having "protheca" or the perforated wall in outer volutions, but the former differs from the latter in its larger shell with more gentle lateral slopes and more bluntly pointed poles.

Protriticites fusulinelloides SHENG and SUN, 1975, from the Middle Carboniferous of Qinghai, central part of China can be easily distinguished from *P. toriyamai* by its more elongated fusiform and much larger shell.

Protriticites praemontiparus ZHOU, SHENG and WANG, 1987, from *Protriticites subschwagerinoides* zone, Xiaodushan, Guangnan, eastern Yunnan, South China, differs from *P. toriyamai* in its larger and more fusiform to ellipsoidal shell. *Protriticites minor* ZHOU, SHENG and WANG, 1987, from the *Protriticites subschwagerinoides* zone of Xiaodushan, eastern Yunnan, is also similar in its outline and size to *P. toriyamai.*

However, *P. toriyamai* can be distinguished from *P. minor* by its smaller proloculus and more bluntly pointed poles.

Occurrence: *Protriticites toriyamai* is common at Loc. MA66, Mt. Maruyama, Isa Quarry, Mine City, Yamaguchi Prefecture. It is associated with *P. yanagidai* and *P. masamichii,* and rarely with *P.* aff. *matsumotoi* (KANMERA).

Geological age: Late Carboniferous (Kassimovian), *Protriticites matsumotoi* zone of the Akiyoshi Limestone Group.

Repository: The holotype, KMNH IvP 400,005 is preserved in Kitakyushu Museum and Institute of Natural History. Remainders of the studied materials are divided by the Kitakyushu Museum and Institute of Natural History and Mine City Museum.

***Protriticites* aff. *matsumotoi* (KANMERA)**

Pl. 3, figs. 5–6

Compare:

1955. *Triticites matsumotoi* KANMERA. *Japan. Jour. Geol. Geogr.*, vol. 26, no. 304, p. 184–186, pl. 11, figures 6–25.
1977. *Triticites* (s.l.) *matsumotoi,* M. OTA. *Bull. Akiyoshi-dai Sci. Mus.*, no. 12, pl. 2, figures 13–14.
1990. *Montiparus matsumotoi,* OZAWA and KOBAYASHI (partim). *Guide book of Benthos '90,* pl. 4, figure 4 (non figure 5).
1993. *Protriticites matsumotoi,* Y. OTA and M. OTA. *Bull. Akiyoshi-dai Mus. Nat. Hist.*, no. 28, pl. 1, figures 4–5.

Material: Tangential section: MA66(3c)-1, KMNH IvP 400,008 from Loc. MA66. Oblique section: MA66(2-3), MMHF100074 from Loc. MA66.

Locality: Loc. MA66, at the Mt. Maruyama, Isa Quarry, Mine City, Yamaguchi Prefecture.

Description: The available specimens at hand are incomplete, and are composed of oblique sections. The shell is medium in size and fusiform in shape, with a constantly straight coiling axis, convex lateral slopes and bluntly pointed poles. Because of incomplete specimens, the definite dimension of shell is not confirmed. However, 1.73 mm in half length, and 2.01 mm wide in four and a half volutions are ascertained. The shell is short in early volutions, and becomes slightly elongate fusiform in the mature stage of growth. The ratios of the half length to the radius vector of the first to fourth volution are 1.60, 2.00, 2.90, and 2.64, respectively.

Although the proloculus size and the complete form of shell can not be recognizable, the shell expands slowly in the first to second volution, but rather

rapidly expands in the following volutions. The radius vectors of the first to fourth volution are 0.12, 0.24, 0.36, and 0.53, respectively.

Spirotheca is moderately thick, composed of a tectum, a very thin diaphanotheca, and upper and lower tectoria in the inner volutions, and only a tectum and keriothecal wall in the outer volutions. In well-preserved specimens, outer volutions except keriothecal walls, are composed of a tectum, a lower tectorium, an indistinct and discontinuous transparent layer and an inconstant upper tectorium. The thicknesses of spirotheca of the first to fourth volution are 0.024, 0.043, 0.058, and 0.062 mm, respectively.

Chomata are relatively massive. The tunnel is narrow in the inner volutions but becomes slightly wider in the outer ones. It is about a half or slightly less than a half as high as the chamber. Tunnel angles in the first to fourth volution are 13, 26, 27, and 28 degrees, respectively.

Remarks and comparison: This species is so difficult to confirm the definite specific position because of the poor state of preservation.

However, this species is characterized by its remarkably large size, approximate-

Table 5. Measurements (in mm) of *Protriticites* aff. *matsumotoi* (KANMERA).

	L.	W.	R.	Prol. D
MA66(3c)-1	3.63+	2.01+	1.80±	0.07

Radius vector						
volution	1	2	3	4	5	6
MA66(3c)-1	0.12	0.24	0.36	0.53	0.91+	

Ratio of Hl./Rv.						
volution	1	2	3	4	5	6
MA66(3c)-1	1.60	2.00	2.90	2.64	1.89±	

Thickness of spirotheca						
volution	1	2	3	4	5	6
MA66(3c)-1	0.024	0.043	0.058	0.062	0.062	

Tunnel angle						
volution	1	2	3	4	5	6
MA66(3c)-1	13	26	27?	28		

ly twice the whorl diameter of the preceding three species, and having the "*Protriticites*-type wall" in outer volutions.

These two main characters of the present species are common to those of *Protriticites matsumotoi* (KANMERA, 1955), and both species are closely related to each other. KANMERA (1955) established the species *matsumotoi* under the name of *Triticites*. KANMERA (1955) remarked that the mature specimens of this species had the spirotheca with discernible keriotheca in the fifth and the following volutions, and also had some *Fusulinella* like-wall structures. ISHIZAKI (1963) noticed that the "*Triticites*" *matsumotoi* KANMERA should be referable to the genus *Protriticites*. ISHII (1990) established the *Protriticites* (*P.*) *matsumotoi* zone below the *Triticites yayamadakensis* zone. Here, the author treated "*Triticites*" *matsumotoi* KANMERA, 1955, as a species of the genus *Protriticites*.

OZAWA and KOBAYASHI (1990) referred *Protriticites matsumotoi* to the genus *Montiparus* by ROZOVSKAYA (1948, 1950). However, their specimen (Plate 4, figure 4) should be referred to the genus *Protriticites,* because it has the well-developed fusiform shape with sharply pointed poles.

OZAWA *et al.* (1990) also reported *Montiparus matsumotoi* (KANMERA). However, the specimens they discussed are probably not assignable to *Protriticites matsumotoi* but are considered to be related to *Montiparus matsumotoi inflatus,* reported by WATANABE (1991).

The present species is closely related to *Protriticites matsumotoi* (KANMERA). However, it may be distinct from the latter species by the differences observed on chomata and number of the "*Protriticites*-type wall".

More materials and further studies are required to give a final specific determination for the Maruyama's specimens.

Occurrence: *Protriticites* aff. *matsumotoi* (KANMERA) shows very rare in occurrence from Loc. MA66. It is accompanied by abundant specimens of *P. yanagidai* and *P. masamichii,* and common ones of *P. toriyamai.*

Geological age: *Protriticites matsumotoi* (KANMERA) was originally reported from the "*Triticites*" (s.l.) *matsumotoi* subzone (KANMERA, 1955) of the Carboniferous to Permian Yayamadake Limestone of the Hikawa Valley, Kumamoto Prefecture, Kyushu, Japan. This subzone is partly correlated with the *Protriticites matsumotoi* zone in the Akiyoshi Limestone Group. Late Carboniferous (Kassimovian).

Repository: The tangential section, KMNH IvP 400,008 is preserved in Kitakyushu Museum and Institute of Natural History. Remainders of studied materials will be divisibly kept in the Kitakyushu Museum and Institute of Natural History and Mine City Museum.

Concluding Remarks

On the basis of the genus *Protriticites* from the Mt. Maruyama area, some comments on the characteristics of three new species, *Protriticites yanagidai, P. masamichii* and *P. toriyamai* will be given here to clarify the relationship among the new species.

These new species are all characterized by their small size. Both *P. yanagidai* and *P. masamichii* are of the almost same size, ranging in length from 2.00 to 2.50 mm (Figs. 7–9). However, *P. yanagidai* has the fusiform shape, whereas *P. masamichii* is characterized by its oval to subspherical form. The data on the increasing rate of half-length per a volution also well indicates that *P. masamichii* has the more inflated form than *P. yanagidai* (Figs. 10–12). *Protriticites toriyamai* is the smallest fusulinid obtained from Loc. MA66. However, there is no possibility on *P. toriyamai* that it represents a younger ontogenetic stage of *P. yanagidai* or *P. masamichii*, because *P. toriyamai* has a shell in five volutions. *Protriticites* aff. *matsumotoi* (KANMERA) is characterized by its large size, about twice as large as *P. yanagidai* or *P. masamichii* has in axial length.

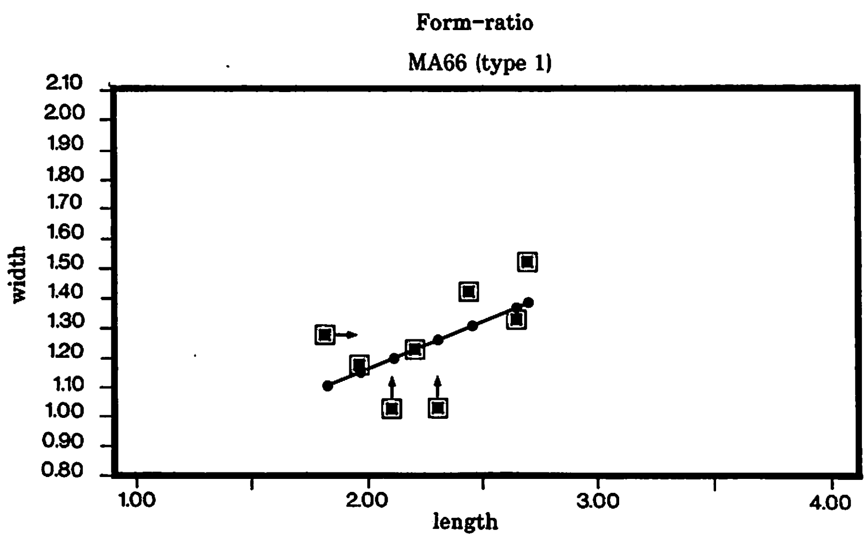

Fig. 7. Scatter diagram showing variation of ratios between length and width of *Protriticites yanagidai* sp. nov. (Arrows indicate the extrapolated proportions of incomplete specimens.)

Four species of *Protriticites, P. yayagidai, P. masamichii, P. toriyamai* and *P.* aff. *matsumotoi* (KANMERA) from the Mt. Maruyama area are definitely distinguished with each other by their morphological characteristics.

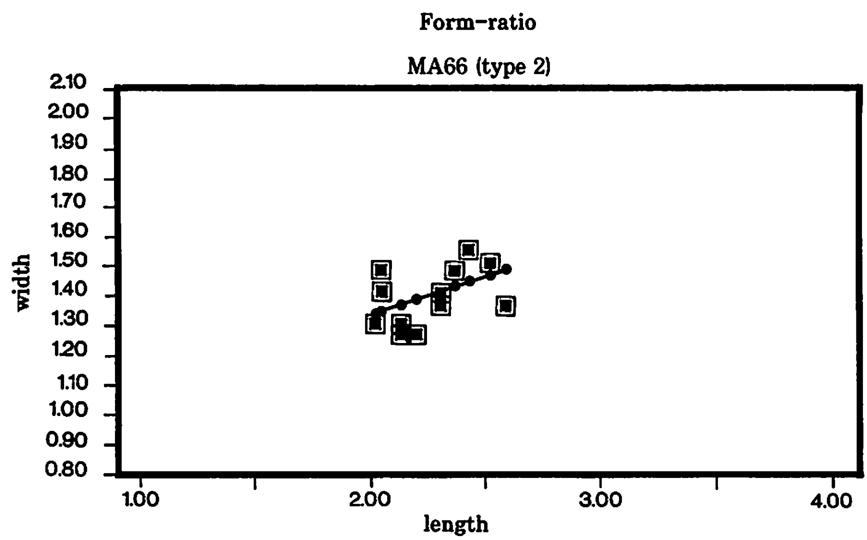

Fig. 8. Scatter diagram showing variation of ratios between length and width of *Protriticites masamichii* sp. nov.

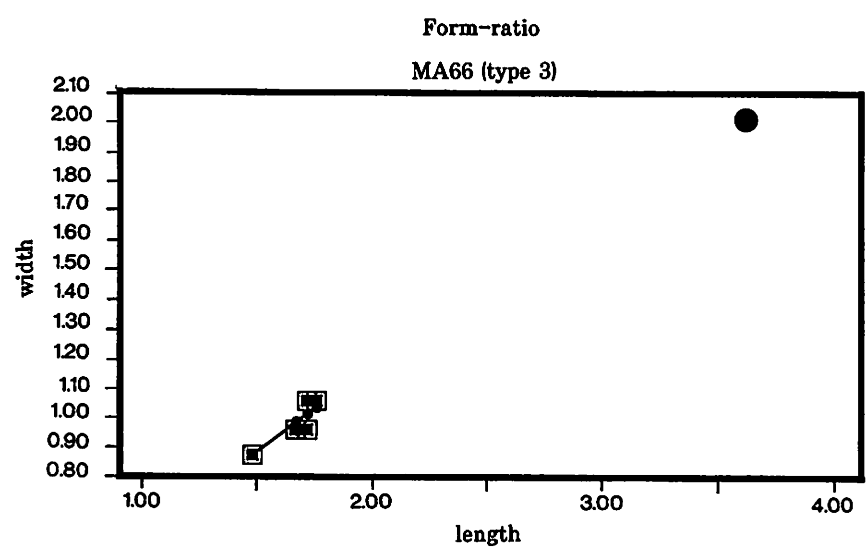

Fig. 9. Scatter diagram showing variation of ratios between length and width of *Protriticites toriyamai* sp. nov., and *Protriticites* aff. *matsumotoi* (KANMERA). (Black circle indicates *Protriticites* aff. *matsumotoi* (KANMERA).)

Stratigraphical consideration of the Mt. Maruyama area

The following concluding remarks on stratigraphy and paleoenvironment of the Mt. Maruyama area are summarized.

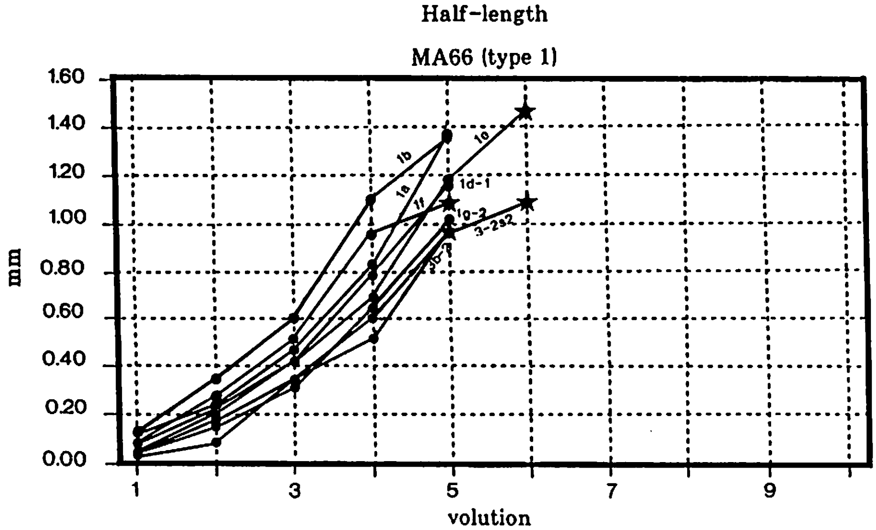

Fig. 10. Half length of *Protriticites yanagidai* sp. nov. Asterisk: (**n**-1) and one half volution(s); **n**, number of volutions.

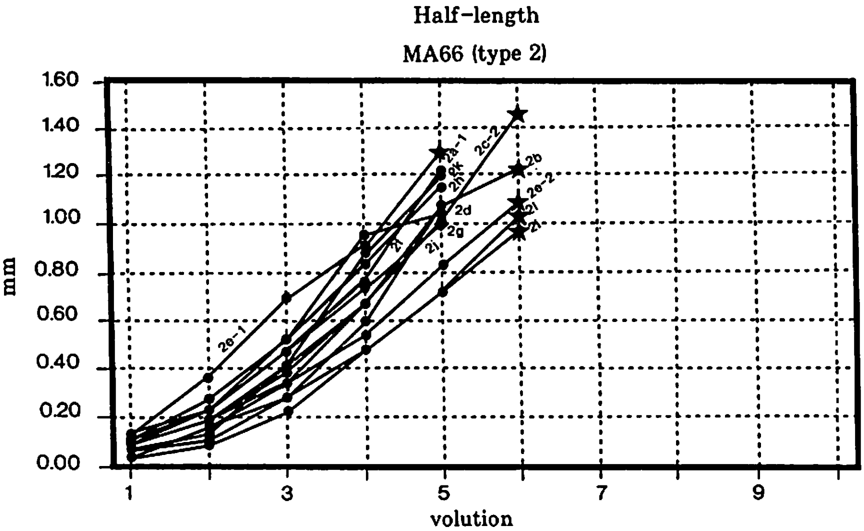

Fig. 11. Half length of *Protriticites masamichii* sp. nov. Asterisk: (**n**-1) and one half volution(s); **n**, number of volutions.

The lithologic facies and sedimentary features of the Mt. Maruyama area well indicate the successive carbonate depositions near the reef core in the Akiyoshi organic reef complex. The lithologic data obtained from Loc. MA66 permit a

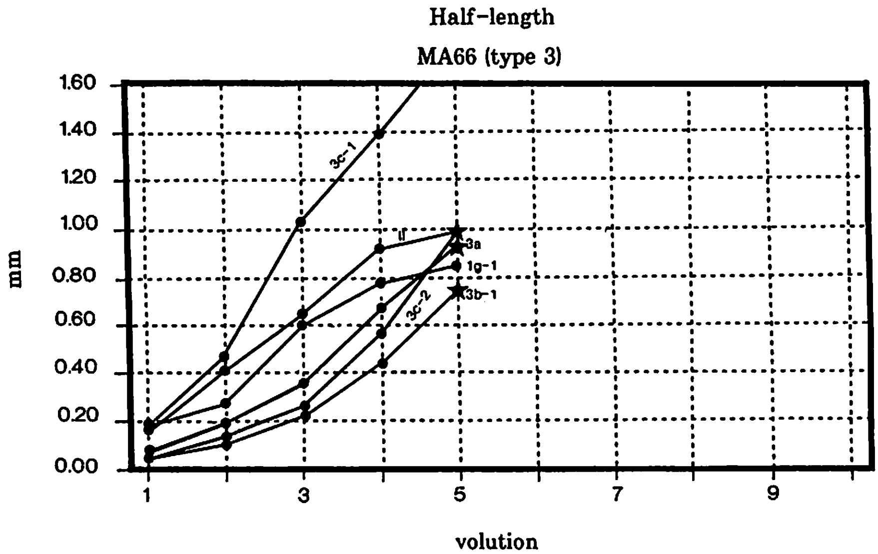

Fig. 12. Half length of *Protriticites toriyamai* sp. nov. Number 3c-1 only shows the data of *Protriticites* aff. *matsumotoi* (KANMERA). Asterisk: (**n**-1) and one half volution(s); **n**, number of volutions.

reconstruction of the following depositional environment, such as the by-pass margin or reef flat in the Akiyoshi organic reef complex. These concluding remarks on paleoenvironmental consideration well support those by OTA (1968) and KYUMA and NISHIDA (1987). Fusulinid assemblages from Loc. MA66 are comparable with those of the *Triticites* (s.l.) *matsumotoi* zone of the formerly summarized regional zonations (OTA, 1977) and the newly established *Protriticites matsumotoi* zone (OTA and OTA, 1993), because four fusulinid species from Loc. MA66 show the close alliance to *Protriticites matsumotoi* (KANMERA, 1955).

Furthermore, the new species: *Protriticites yanagidai, P. masamichii* and *P. toriyamai* are all closely related to *Protriticites praemontiparus* ZHOU, SHENG and WANG, 1987, and *P. minor* ZHOU, SHENG and WANG, 1987 from eastern Yunnan, South China. Judging from affinities of the species and the viewpoint of paleogeography, it is probable that the fusulinid assemblages in the Akiyoshi organic reef complex were closely related to that of S. China in late Carboniferous time.

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摘　　要

山口県美祢市丸山の上部石炭系産フズリナ類

太 田 泰 弘

美祢市歴史民俗資料館

山口県美祢市丸山には，石炭紀中期から後期にわたる秋吉石灰岩層群が広く分布する．

本地域に分布する石灰岩は，秋吉生物礁複合体の主要構成要素であるアンモノイドのゴニアタイト類，腕足類，四放サンゴなどの大型化石類，及び phylloid algae などの藻類を多産し，部分的にフズリナ類を産出する．

生相・岩相の特徴から，本地域の石灰岩堆積場は，秋吉生物礁複合体における reef-flat 部，あるいは fore-reef 部から open sea に通ずる by-pass margin 部として復原される．

また調査地域内の MA66 地点において，primitive-type の "*Triticites*" 群集の密集層が発見され，鏡下観察に基付く検討の結果，新種3種を含む以下の様な4種のフズリナ類を識別した．

すなわち *Protriticites yanagidai* Y. OTA, **sp. nov.**, *Protriticites masamichii* Y. OTA, **sp. nov.**, *Protriticites toriyamai* Y. OTA, **sp. nov.** および *Protriticites* aff. *matsumotoi* (KANMERA) である．

Upper Carboniferous Fusulinids from Mt. Maruyama, Mine City, Yamaguchi Prefecture

Yasuhiro OTA

Plates 1–3

Explanation of Plate 1

Figs. 1–7. *Protriticites yanagidai* sp. nov.

1a. Axial section of the holotype, KMNH IvP 400,001 (MA66(1a)), ×20 (Short scale bar: 1 mm).

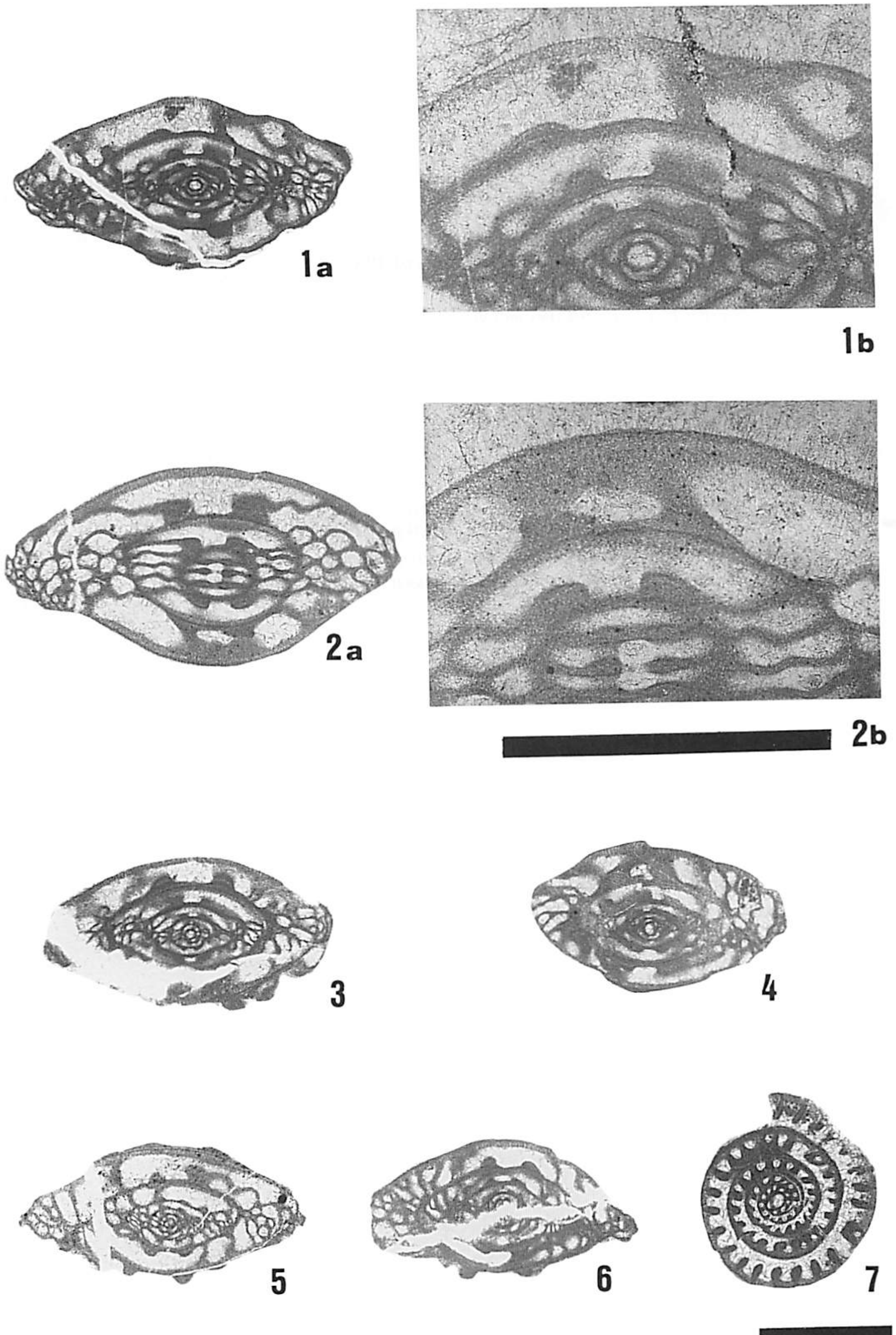
1b. Enlarged figure of a part of Fig. 1a, ×50 (Long scale bar: 1 mm).

2a. Tangential section of a paratype, MMHF100056 (MA66-1(I)-2), ×20.

2b. Enlarged part of the same specimen as Fig. 2a, ×50

3–6. Axial sections of the paratypes, respectively: 3, MMHF 100058 (MA66(3-2s2)), ×20; 4, MMHF100057 (MA66(3b-2)), ×20; 5, MMHF100054 (MA66(1f)), ×20; 6, MMHF100055 (MA66(1g)-2), ×20.

7. Sagittal section of a paratype, KMNH IvP 400,002 (MA66(1sa)), ×20.


1a
1b
2a
2b
3
4
5
6
7

Explanation of Plate 2

Figs. 1–7. *Protriticites masamichii* sp. nov.

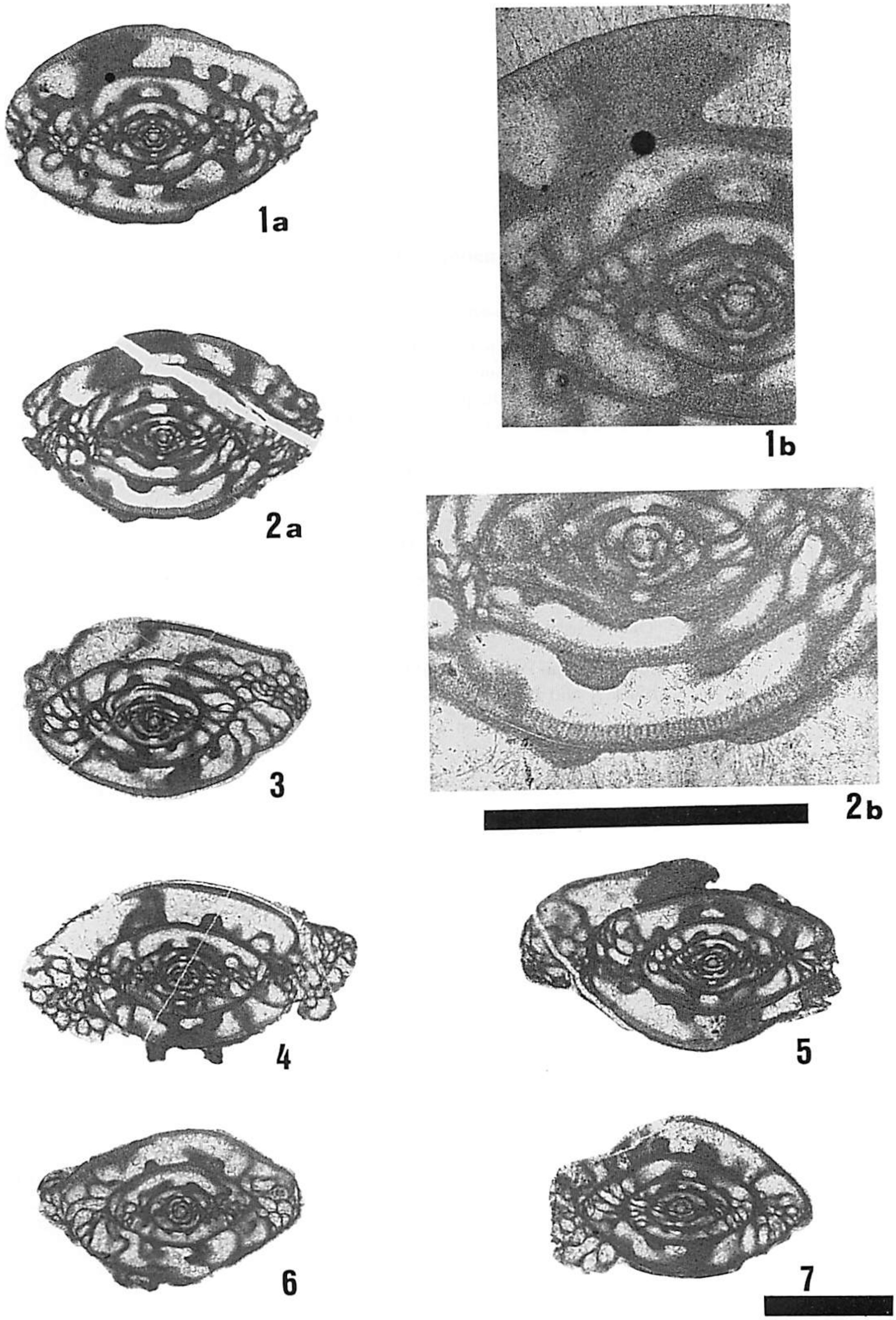
1a. Axial section of the holotype, KMNH IvP 400,003 (MA66(2a-1)), ×20 (Short scale bar: 1 mm).

1b. Enlarged figure of a part of Fig. 1a, ×50 (Long scale bar: 1 mm).

2a. Axial section of a paratype, MMHF100060 (MA66(2b)), ×20.

2b. Enlarged part of the same specimen as Fig. 2a, ×50.

3–7. Axial sections of the paratypes, respectively: 3, MMHF100062 (MA66(2d)), ×20; 4, MMHF100063 (MA66(2e-1)), ×20; 5, MMHF100061 (MA66(2c-2)), ×20; 6, MMHF100066 (MA66 (2h)), ×20; 7, MMHF100068 (MA66(2j)), ×20.


1a
1b
2a
2b
3
4
5
6
7

Explanation of Plate 3

Figs. 1–4. *Protriticites toriyamai* sp. nov.

1. Axial section of the holotype, KMNH IvP 400,005 (MA66(3a)), ×20 (Scale bar: 1 mm).

2–3. Axial sections of the paratypes, respectively: 2, KMNH IvP 400,006 (MA66(3c)-2), ×20; 3, MMHF100072 (MA66(3b)-1), ×20.

4. Sagittal section of a paratype, KMNH IvP 400,007 (MA(3-1s)), ×20.

Figs. 5–6. *Protriticites* aff. *matsumotoi* (Kanmera)

5. Tangential (slightly oblique) section, KMNH IvP 400,008 (MA66 (3c)-1), ×20.

6. Oblique section, MMHF100074 (MA66(2-3)), ×20.

Fig. 7. Outcrop (lapie) of Loc. MA66, and the collected materials (Block A and Block B).

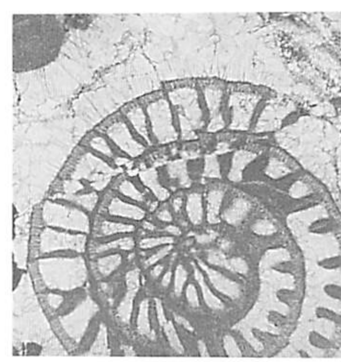
1

2

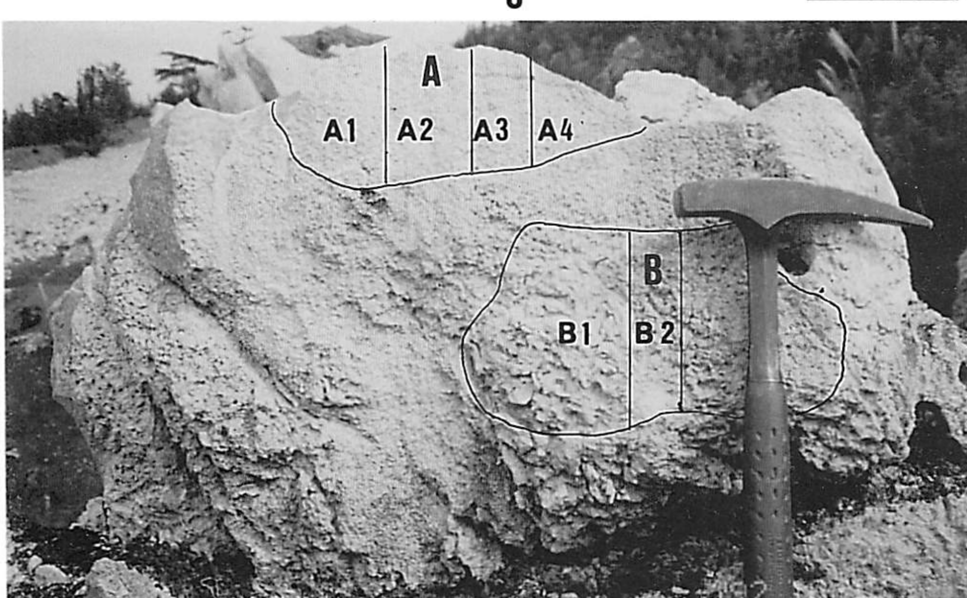
3

4

5



6



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